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OXYGEN DEFICIENCY HAZARDS ASSOCIATED WITH LIQUEFIED GAS SYSTEMS
DEVELOPMENT OF A PROGRAM OF CONTROLS

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The use of liquefied gases in industry and research has become commonplace. Release into the atmosphere of these gases, whether intentional or not, will result in a displacement of air and a reduction in the oxygen concentration. Exposure to reduced levels of oxygen levels may cause reduced abilities, unconsciousness, or death.

This paper describes the derivation of a novel program of controls for oxygen deficiency hazards. The key to this approach is a quantitative assessment of risk for each planned operation and the application of control measures to reduce that risk to an acceptable level. Five risk levels evolve which are based on the probability of fatality. Controls such as training, oxygen monitoring equipment, self-rescue respirators, and medical surveillance, are required when the probability of fatality exceeds 10^{-7} per hour. The quantitative nature of this program ensures an appropriate level of control without undue burden or expense.

introduction

The release of a liquefied gas to the atmosphere results in a rapid evaporation and expansion to about 700 times its initial volume. Therefore, even small leaks in liquefied gas systems can cause the surrounding atmosphere to become oxygen deficient, explosive, or toxic; depending on the properties of the gas. This paper is concerned only with potential oxygen deficiencies generated from accidental releases of gases which are non-toxic and non-explosive such as the noble gases. Persons exposed to a reduced-oxygen atmosphere may experience reduced abilities, unconsciousness, or even death.

The heretofore accepted control procedure for this hazard involves the calculation of the oxygen concentration which would result from the worst possible accident. If it is possible for personnel to be exposed to an oxygen-deficient atmosphere, then appropriate measures are taken; usually some sort of confined space protocol. Except for the calculation of the lowest possible oxygen concentration, this process is subjective, depending largely on the experience of the evaluator and the safety posture of the employer. Therefore, it is difficult to determine if the level of control is appropriate. Usually this is not a problem since fatalities are rare and the exposed population is typically small. But with a large exposed population it is necessary to implement an appropriate level of control. Too little control and the rate of injuries and fatalities will be unacceptably high. Too much control and the cost of doing the job may be restrictive.

At Fermilab large quantities of liquefied gases are employed in high energy physics research. Those most commonly used are liquid nitrogen (LN2), liquid helium (LHe), and liquid argon. A major program presently is underway to construct, install, and operate a proton synchrotron ring consisting of about 1000 superconducting magnets, the incorporation of which will increase the maximum energy of accelerated protons from 400 GeV, attainable with presently installed conventional magnets, to 1000 GeV (1 TeV). The 2 km diameter ring will contain about 20,000 liters of LHe and 12,000 liters of LN2. The associated helium reliquefaction plant will contain approximately 5000 liters of LHe and 48,000 liters of LN2 for a system total of 25,000 liters of LHe and 60,000 liters of LN2. Other operations at Fermilab which employ liquefied gases in quantities between 200 and 40,000 liquid liters each include:

1. Superconducting magnets for beam transport,

2. Superconducting spectrometer magnets for high energy physics experiments,

3. Liquid argon calorimeters for high energy physics experiments,

4. Component testing for superconducting systems,
5. Liquefaction of helium for use elsewhere on site, and
6. Materials applications (e.g., purge gas source).

In the majority of instances the liquefied gases are stored or used within enclosed habitable structures, which compounds the potential for an oxygen deficiency. It is estimated that 400-500 persons will be involved in liquefied gas operations which present a significant risk of oxygen deficiency.

Although Fermilab is a large user of liquefied gases, its use represents only a small fraction of the total. The largest quantities are found in air separation plants and in food freezing. Other large particle accelerators also have or plan applications similar to those of Fermilab. In addition, there are many potential large applications of superconductivity which are presently in the development stage. These include magnets for medical NMR imaging, magnetically confined nuclear fusion, magnetic levitation, and electrical power generation, transmission, and storage.

This paper describes the derivation of the Fermilab Oxygen Deficiency Hazards (ODH) Program, which is intended to protect persons from potential oxygen deficiencies which may arise from the operation of large liquefied gas systems. It is based on an analysis of the the following: effects of exposure, existing standards, fatality rates for various activities, failure mechanisms in liquefied gas systems, and hazard control techniques. Application of the program generally involves the assessment of fatality rates for persons engaged in operations near liquefied gas systems. Protective measures are prescribed which reduce the fatality rate to an acceptable level. This approach is quantitative and it allows for an appropriate set of controls to be implemented.

effects of exposure

Air normally contains about 21% oxygen with the remainder consisting mostly of nitrogen. Individuals exposed to reduced oxygen atmospheres stand to suffer a variety of harmful effects. Table I contains a list of some of these effects and the sea level oxygen concentrations at which they occur.

At even higher altitudes the same effects generally will occur at greater volume concentrations since the partial pressure of oxygen is decreased. This statement must be qualified since persons can become acclimatized to moderate reductions in oxygen. The effects of exposure to reduced oxygen generally are reversible if exposure is terminated early enough. If not, permanent central nervous system damage or lethality result. Perhaps the most important effect, as far as preventing escape from the vicinity of an oxygen deficiency, is unconsciousness. Figure 1 is a plot of time of useful consciousness versus %O_2 for seated individuals (sea level). The threshold for this effect is about 11%. Between 0 and 5% only a 10-15 s exposure is required to produce unconsciousness. The threshold of unconsciousness for active persons is higher, about 13%[7], because the rate of oxygen consumption in the body is increased with exercise.

In general, the intensity of the effects increases rapidly with decreasing oxygen concentration and increasing exposure duration: first a reduction of abilities (senses, judgment, motor skills) occurs, then unconsciousness, and finally death. It is concluded that any acute exposure to an atmosphere containing less than 17% oxygen presents a risk.

program derivation

The program must address two broad types of exposure: one in which an oxygen deficiency exists and another in which there is not an oxygen deficiency, but where the potential exists for one to occur. The following discussion will describe the logical development of procedures for each of these exposure situations as well as escape and rescue procedures.

The first step in developing procedures for operations occurring in oxygen deficient atmospheres was to define what is meant by "oxygen deficiency". Federal regulations and national consensus standards provide a variety of values (Table II). Ranging from 16.0 to 19.5%, most are presented in terms of volume percent of oxygen at sea level, and none is universally accepted. Therefore it was necessary to investigate the problem further in order to derive an appropriate value.

For the purposes of optimizing safety, it is desirable to maximize the oxygen concentration used as the definition of "oxygen deficiency". As was mentioned in the previous effects discussion that the first harmful effects occur at about 17%, therefore the adopted value should certainly be greater than or equal to this. Other national laboratories contacted use 19.5% (Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Livermore Laboratory, and Los Alamos National Laboratory). Our experience with oxygen monitoring equipment suggested that an instrument drift of at least +-1% oxygen could be expected. Therefore, the trip level on oxygen monitoring equipment would necessarily have to be set 1% higher than the truly hazardous level.

For operational convenience, it is desirable to minimize the selected value. There would be situations where operations would be shut down because the oxygen concentration was below the deficiency level. The lower the deficiency level was defined, the fewer the operations that would be interrupted. In addition, we experienced weekly false alarms when trip levels of the oxygen monitoring equipment were set at 19.5%. The operational inconvenience resulting from these false alarms was considerable. Typically access to buildings in which oxygen levels below 19.5% were indicated would be prohibited until a specified individual arrived on the scene to declare the alarm to be false (usually on off-hours). Also, personnel were becoming inured to the oxygen alarms.

A level of 18% oxygen was adopted as the Fermilab standard. This value provided the 1% margin of safety over the threshold for any harmful effects and completely eliminated the false alarms. The 18% value falls in the range of recommended standards and is the one recommeded by the ACGIH.

According to previously existing Fermilab Policy, work in atmospheres containing less than 19.5% oxygen required the use of a self contained breathing apparatus (SCBA) or an airline respirator with an escape bottle. The policy was amended to decrease the oxygen concentration from 19.5 to 18% with the procedures left unchanged. Additionally, at Fermilab the following are preconditions to allow the use of an SCBA: prior medical approval, prior (and periodic) training in its use, and direct Fire Department supervision of the operation. These procedures are adequate to allow persons to be exposed to an oxygen deficient atmosphere.

At the outset of the operation the oxygen concentration is usually greater than 18%, but it may decrease. In such cases, it is generally impractical to enforce the control measures which are used for oxygen deficient conditions. It was a better approach to provide protective measures in a graduated fashion, i.e., provide protective measures which compensate for the increased risk of fatality from exposure to reduced atmospheric oxygen. This approach requires that:

1. An acceptable fatality rate be defined,
2. A method be devised for determining the excess fatality rate from exposure to reduced atmospheric oxygen, and
3. A scheme of protective measures be devised.

It was decided to use excess fatality rate as the hazard index since death is the primary non-reversible effect of exposure to an oxygen deficiency; most other effects are completely reversible. After careful consideration, it was decided that the national industrial working average fatality rate, 6.5×10^{-8} per hr, would be an acceptable rate. It was concluded that operations near liquified gas systems should be as safe as general industry. It was further decided to "round up" the acceptable value to

1×10^{-7} per hour.

It was established that the fatality rates should be assigned on an operation-by-operation basis and should be averaged over the duration of each operation. For any operation there may be several events which may cause an oxygen deficiency. Each event has a probability of occurrence and each occurrence has a probability of killing someone. We defined the oxygen deficiency hazard fatality rate as

$$\phi = \sum_i P_i \; F_i$$

where ϕ = the ODH fatality rate (per hour),

P_i = the probability of the i^{th} event (per hour), and

F_i = the fatality factor for the i^{th} event.

The summation is over all events which may occur and result in fatality. The value of P_i is determined by operating experience at Fermilab when possible. If no such operating experience is available, then data from similar systems elsewhere, or other relevant data, are used(9). Most often direct operating experience is not available and we make frequent use of failure data compiled by the nuclear industry.

The value of F_i is the probability that a person will die if the event "i" occurs. It depends on how low the oxygen concentration gets and duration of exposure, as well as the difficulty of escape. It often is possible to estimate the value of F_i based on the accident scenario and an understanding of the effects of exposure. For convenience of calculation, a relationship between the value of F_i and the lowest attainable oxygen concentration was defined. It was decided to use the lowest oxygen concentration rather than some average value since this approach was conservative and not enough was understood to allow the definition of an averaging period (for instance). If the lowest oxygen concentration was greater than 18% then the value of F_i would be zero. That is, all exposures above 18% were defined to be "safe" and exposures in this range did not contribute to fatality. However, it was assumed that all exposures to 18% oxygen or lower do contribute to fatality. At very low oxygen concentrations, oxygen deficiency kills directly. At low concentrations unconsciousness occurs, which substantially reduces the probability that an individual will survive the event. At concentrations just below 18%, the senses are dulled and there is a higher than normal probability that the exposed persons will be involved in a fatal accident. Therefore, as the oxygen concentration gets lower, the probability of dying gets much greater. The value of F_i was defined to reflect this dependence.

If the lowest attainable oxygen concentration was 18% then the value of F_i should be 1×10^{-7}. This particular value would cause ϕ to equal 1×10^{-7} per hour if the probability of the event were 1 per hour. If the probability was essentially unity, and the oxygen concentration was equal to 18%, then this operation would be at the threshold for an unaccepatable fatality rate. At lower concentrations the value of F_i should increase. At some point the probability of dying will be unity. At 8.8% oxygen, only about one minute of consciousness is expected and F_i was defined to be unity at this point. The selected function is exponential. The value of F_i as a function of lowest attainable oxygen concentration during an event is shown in Figure 2.

The protective measures are implemented in a fashion which reduces the excess risk of fatality from exposure to an oxygen deficient atmosphere to no more than 1×10^{-7} per hour. Something is done whenever this rate is exceeded. The first step is to provide some sort of oxygen monitoring equipment since an oxygen deficient atmosphere is not obvious to the senses. The choice is made whether to use area oxygen monitors, personal oxygen monitors, or some combination of both. Area monitors can provide continuous monitoring and can be connected to access interlock systems or to data acquisition systems to yield failure data. In addition, area monitors provide protection to untrained bystanders. There are several disadvantages to the use of area monitors. It is inconvenient to calibrate area monitors at intervals which would preclude drift in excess of +-1% oxygen. It may be economically unfeasible to install enough sensors to insure all occupied locations are monitored. The advantage of providing coverage for bystanders is not great if bystanders do not know what to do if they hear the alarm.

Personal oxygen monitors have the distinct advantage of measuring the oxygen concentration at the worker. In addition, these devices could be calibrated daily or more frequently which would minimize instrument drift. Personal monitors also are easy to make failsafe since they would be tested at least daily in a normal atmosphere. Failures would be readily noticed. However, they cannot insure coverage for bystanders and cannot be connected to security interlocks.

Personal monitors were selected for use largely because they measure the concentration of oxygen at the worker, are frequently calibrated, and are easy to make failsafe. In addition, they are less expensive than a system of area monitors which provide equal protection.

A failure probability of 0.01 per demand was assigned to personal oxygen monitors based on the expected error-of-omission rate, i.e., failure to put them on, failure to turn them on, etc. The rate at which the oxygen monitor itself would fail with no indication was estimated to be less that 0.0001, and thus was neglected. Therefore, if a person were equipped with a personal oxygen monitor, he would reliably be warned of an oxygen deficient condition 99 out of 100 times. If the warning always resulted in safe escape, then work could be allowed for operations which had an ODH fatality rate up to 1×10^{-5} per hour. In some situations, a self-rescue supplied atmosphere respirator may be necessary to escape.

In order to allow work which had an ODH fatality rate of up to 1×10^{-3} per hour, it was decided to require at least two trained and equipped persons be present at the operation. They would each have an oxygen monitor with a failure frequency of 0.01 per demand; the combined failure rate would be 0.0001 (assuming two monitors and independent failures of the monitors). All the personnel would be exposed to the hazard, which reduces their ability to survive. However, they would not be in exactly the same place and the critical failure in this case is in the ability to monitor the oxygen concentration. It was concluded that the multiple oxygen monitor argument could not be extended beyond two monitors because the probability of escape becomes the limiting factor and not the probability of knowing an oxygen deficiency exists.

To permit participation in operations which had ODH fatality rates up to 1×10^{-1} per hour, the requirement for an unexposed observer was added. This observer would maintain continuous surveillance of the operation and summon help if needed. The observer must not be exposed to the hazard and must not attepmt to rescue workers himself. The people engaged in the operation must be appropriately trained and equipped with personal oxygen monitors and, if appropriate, self-rescue supplied atmosphere respirators. Participation in an operation with an ODH fatality rate in excess of 1×10^{-1} per hour requires the same controls as those for an oxygen deficient environment.

These stepped control procedures readily lend themselves to a hazard class system. Table III lists the ODH Class as a function of the ODH fatality rate. For each ODH Class there is a specific set of control measures which reduces the probability of excess fatalities from exposure to reduced atmospheric oxygen to 1×10^{-7} per hour or less.

The foregoing presumes that there is a high probability that workers will escape from an oxygen deficient situation when properly warned. In order to insure this, a program of medical surveillance was established. It was concluded that the following minimum abilities would allow workers to perform satisfactorily in any necessary escape and rescue procedures:

1. Sufficiently acute hearing to recognize an audible oxygen alarm and understand instructions shouted in an emergency;

2. Sufficiently acute vision to see an escape route and any visual emergency escape information;

3. Cardio-pulmonary function adequate to allow the following:

* Brief exposure to an atmosphere with an oxygen concentration less than 18%,

* Physical exertion as required for escape, and/or

* Use of a self-rescue supplied atmosphere respirator;

(The duration of exposure to reduced oxygen would be limited by the time to escape or the time to activate and don a self-rescue respirator.)

4. Sufficient ambulatory capabilities to permit escape;

5. Emotional stability sufficient to preclude panic in the event of an oxygen deficiency.

It is likely that personnel engaged in Class 1 or greater operations will be exposed to reduced oxygen atmospheres more frequently than will other personnel. These uncontrolled exposures to atmospheres containing oxygen concentrations as low as 18% must not significantly increase the probability of fatality, either through direct or indirect mechanisms. At Fermilab, medical surveillance for ODH work is provided by the medical department.

Warning signs were developed which state the requirements explicitly for each of the ODH Classes. These signs, shown in Figure 3, comply with the ANSI standard for safety signs[10]. They are required to be posted at all entry points to an operation which is ODH Class 1 or greater.

The emergency evacuation and rescue plan is shown in a flow diagram in Figure 4. The basis of the procedures is that the Fermilab Fire Department is to conduct all rescues. The personnel engaged in the operation are primarily resonsible to see that they, themselves, escape. Personnel may assist others while they are leaving the area, but only to the extent that they do not significantly endanger themselves. This is important, since persons not trained and equipped to conduct rescue quite often wind up as victims themselves. Please note that the first two boxes are procedures which occur before personnel are exposed to the operation.

It often is difficult to predict the occurrence of small leaks from cryogenic systems. In order to prevent an oxygen deficiency from occurring due to these leaks, a minimum ventilation rate requirement of one volume change per hour was established for Class 1 or greater operations. Such a ventilation requirement also provides a recovery mechanism from oxygen deficiencies resulting from large releases of inert gases. One volume change per hour is the minimum recommended for any occupied space in an industrial setting[11].

operating experience

The oxygen deficiency hazard program discussed above has been in effect for about one year at Fermilab. ODH analyses have been carried out for over 50 operations occurring in 20 locations. About one-fourth were found to be ODH Class 0, one-half ODH Class 1, and one-fourth ODH Class 2 through 4. In general the guidelines have been readily accepted and conscientiously observed by laboratory personnel. This is due in part to the objective and quantitative nature of the program, an approach which is palatable to the scientific community. In addition, this quantitative approach readily allows the design and implementation of engineering controls which can reduce the risk of fatality to an acceptable level.

As a result of this program, Fermilab has had to investigate oxygen monitoring equipment. After extensive review of commercially available portable monitors, it was found that none performed well enough to meet the requirements of the laboratory. The laboratory re-engineered a commercial unit in cooperation with the manufacturer. This device is shown in Figure 5. Changes included the addition of an on-off switch which can not be accidentally turned off, the moving of the alarm speaker to the outside of the case, improvement of the belt clip to reduce the likelihood of accidental dropping, changing of the display from continuous to intermittent to extend the life of the batteries, and changing the batteries from single use to rechargeable. The laboratory has purchased about 150 of these portable oxygen monitors to date. They are inexpensive and no failures without alarms have occurred to date.

Although many of the bases for the Fermilab ODH program were arbitrarily selected, they were done so by persons with experience and training in safety and the technology of liquified gas systems. Within these limits the program allows resources to be properly invested: with a balance between getting the job done and making the job safe. It is believed that the approach discussed in this paper can be adopted by other industries which employ large liquified gas systems.

references

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TABLE I

Effect Thresholds for Exposure to Reduced Oxygen[1-4]

(Healthy Individuals at Sea Level)

Volume % Oxygen	Effect
17	Night Vision Reduced Increased Breathing Volume Accelerated Heartbeat
16	Dizziness
15	Impaired Attention Impaired Judgment Impaired Coordination Intermittant Breathing Rapid Fatigue Loss of Muscle Control
12	Very Faulty Judgment Very Poor Muscular Coordination Loss of Consciousness Permanent Brain Damage
10	Inability to Move Nausea Vomiting
6	Spasmatic Breathing Convulsive Movements Death in 5-8 Minutes

TABLE II

Definitions of an Oxygen Deficient Atmosphere

Source	Standard	Volume % at Fermilab *
ACGIH 1982 TLV's	135 mmHg in air	18.2%
ANSI A10.16-1981 (Tunnel Construction)	19.5 volume %	19.5%
ANSI K13.1-1973 (Respirator Cartridges)	19.5 volume % at sea level	20.0%
ANSI Z9.1-1977 (Open-surface Tanks)	19.5 volume % at sea level	20.0%
ANSI Z88.2-1980 (Respiratory Protection)	19.5 volume % at sea level	20.0%
ANSI Z117.1-1977 (Confined Spaces)	18 volume %	18.0%
29 CFR 1910.94 (Ventilation)	19.5 volume %	19.5%
29 CFR 1910.134 (Respiratory Protection)	16.0 volume %	16.0%
29 CFR 1915.81 (Maritime)	16.5 volume %	16.5%
30 CFR 11 (Respirator Approval)	148 mmHg in air	20.0%
NIOSH(4) (Confined Spaces)	132 mmHg in air	17.9%

*Based on an average barometric pressure of 740 mmHg.

TABLE III

Oxygen Deficiency Hazard Classes

ODH Class	ϕ, ODH Fatality Rate (per hour)
0	less than 10^{-7}
1	10^{-7} to 10^{-5}
2	10^{-5} to 10^{-3}
3	10^{-3} to 10^{-1}
4	more than 10^{-1}

Figure Captions

Figure 1 -- Approximate time of useful consciousness as a function of oxygen concentration for seated subjects at sea level.

□ Duration of useful consciousness(5)

○ Duration of useful consciousness(6)

△ Time to coma(5)

▲ "Threshold" for unconsciousness(7)

● Time to unconsciousness(8)

The results from (5) and (6) were converted from high altitude data by the authors.

Figure 2 -- Graph of the logarithm of the fatality factor (F_i) versus the lowest attainable oxygen concentration which can result from a given event. This relationship may be used when no better estimate of the probability of fatality from a given event is available.

Figure 3 -- Oxygen deficiency hazard warning signs used at Fermilab.

Figure 4 -- Oxygen deficiency hazard escape and rescue plan used at Fermilab. (SRSAR = Self-Rescue Supplied Atmosphere Respirator)

Figure 5 -- The personal oxygen monitor engineered and used at Fermilab (Lumidor LP-COM-30).

Figure 1

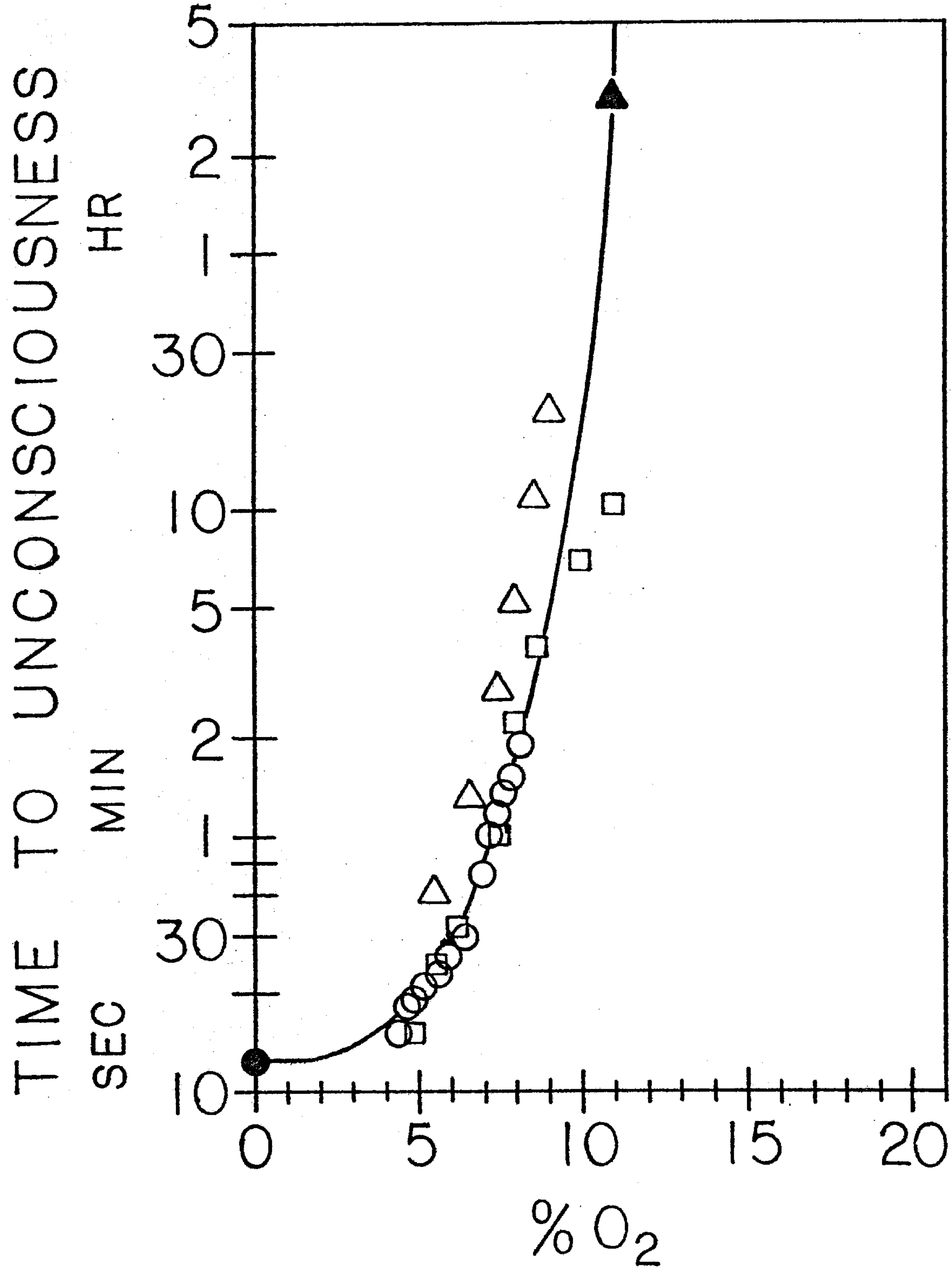
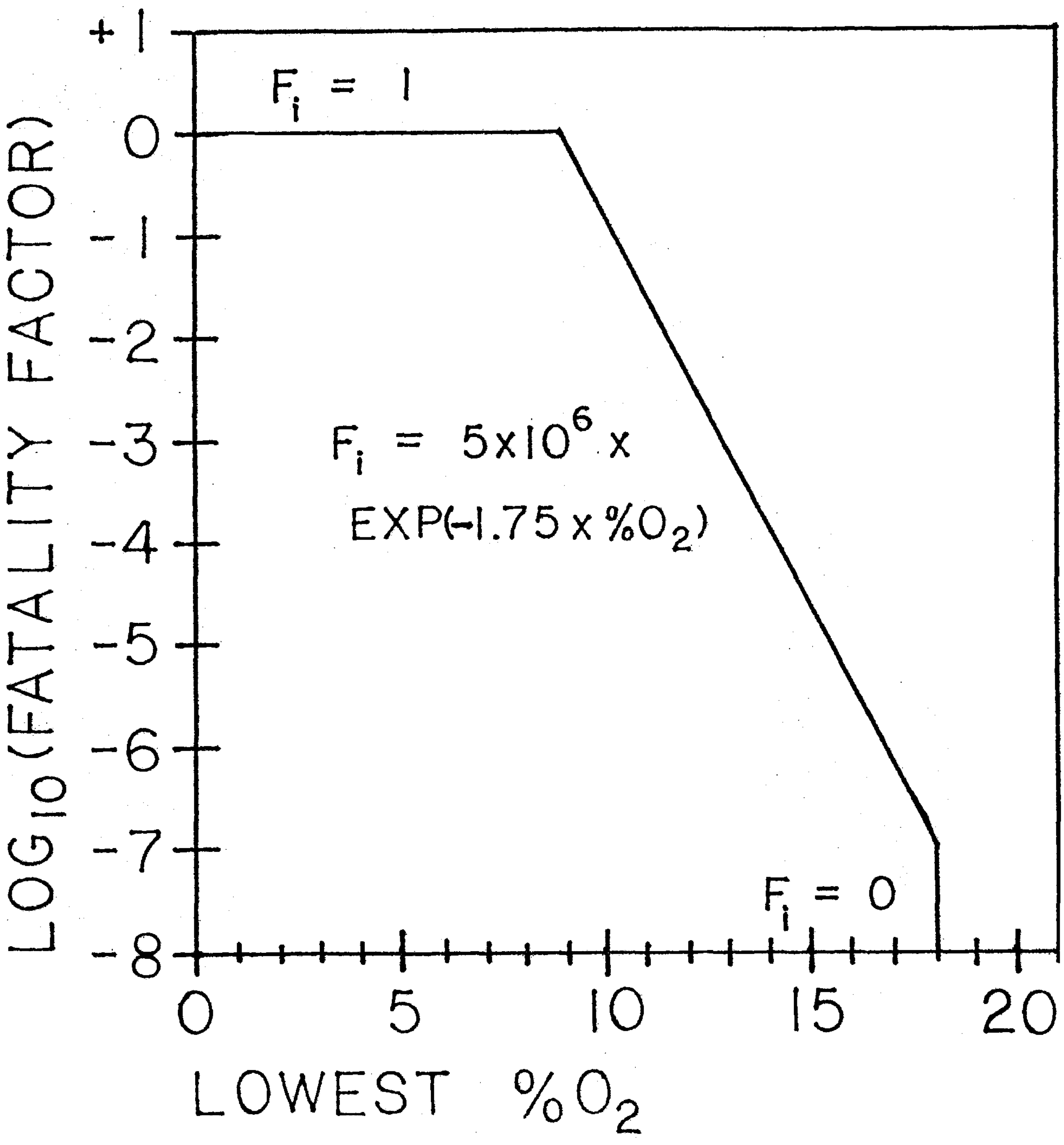

TIME TO UNCONSCIOUSNESS
HR
MIN
SEC
5
2
1
30
10
5
2
1
30
10
0
5
10
15
20
% O_2

Figure 2


+1
0
-1
-2
-3
-4
-5
-6
-7
-8
LOG10(FATALITY FACTOR)
Fi = 1
Fi = 5x10^6 x
EXP(-1.75 x %O2)
Fi = 0
0
5
10
15
20
LOWEST %O2

CAUTION

OXYGEN DEFICIENCY HAZARD 1

PRIOR TO ENTRY, ALL PERSONNEL MUST HAVE THE FOLLOWING:
- . A PERSONAL OXYGEN MONITOR
- . A SELF-RESCUE SUPPLIED ATMOSPHERE RESPIRATOR
- . OXYGEN DEFICIENCY HAZARD TRAINING
- . MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK

ACTIVATE VENTILATION PRIOR TO OCCUPATION.

CAUTION

OXYGEN DEFICIENCY HAZARD 2

PRIOR TO ENTRY, ALL PERSONNEL MUST HAVE THE FOLLOWING:
- . A PERSONAL OXYGEN MONITOR
- . A SELF-RESCUE SUPPLIED ATMOSPHERE RESPIRATOR
- . OXYGEN DEFICIENCY HAZARD TRAINING
- . MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK

MULTIPLE PERSONNEL IN CONTINUOUS COMMUNICATION REQUIRED.
ACTIVATE VENTILATION PRIOR TO OCCUPATION.

DANGER

OXYGEN DEFICIENCY HAZARD 3

PRIOR TO ENTRY, ALL PERSONNEL MUST HAVE THE FOLLOWING:
- . A PERSONAL OXYGEN MONITOR
- . A SELF- RESCUE SUPPLIED ATMOSPHERE RESPIRATOR
- . OXYGEN DEFICIENCY HAZARD TRAINING
- . MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK

RULES FOR ENTRY INTO CONFINED SPACES MUST BE FOLLOWED.
ACTIVATE VENTILATION PRIOR TO OCCUPATION.

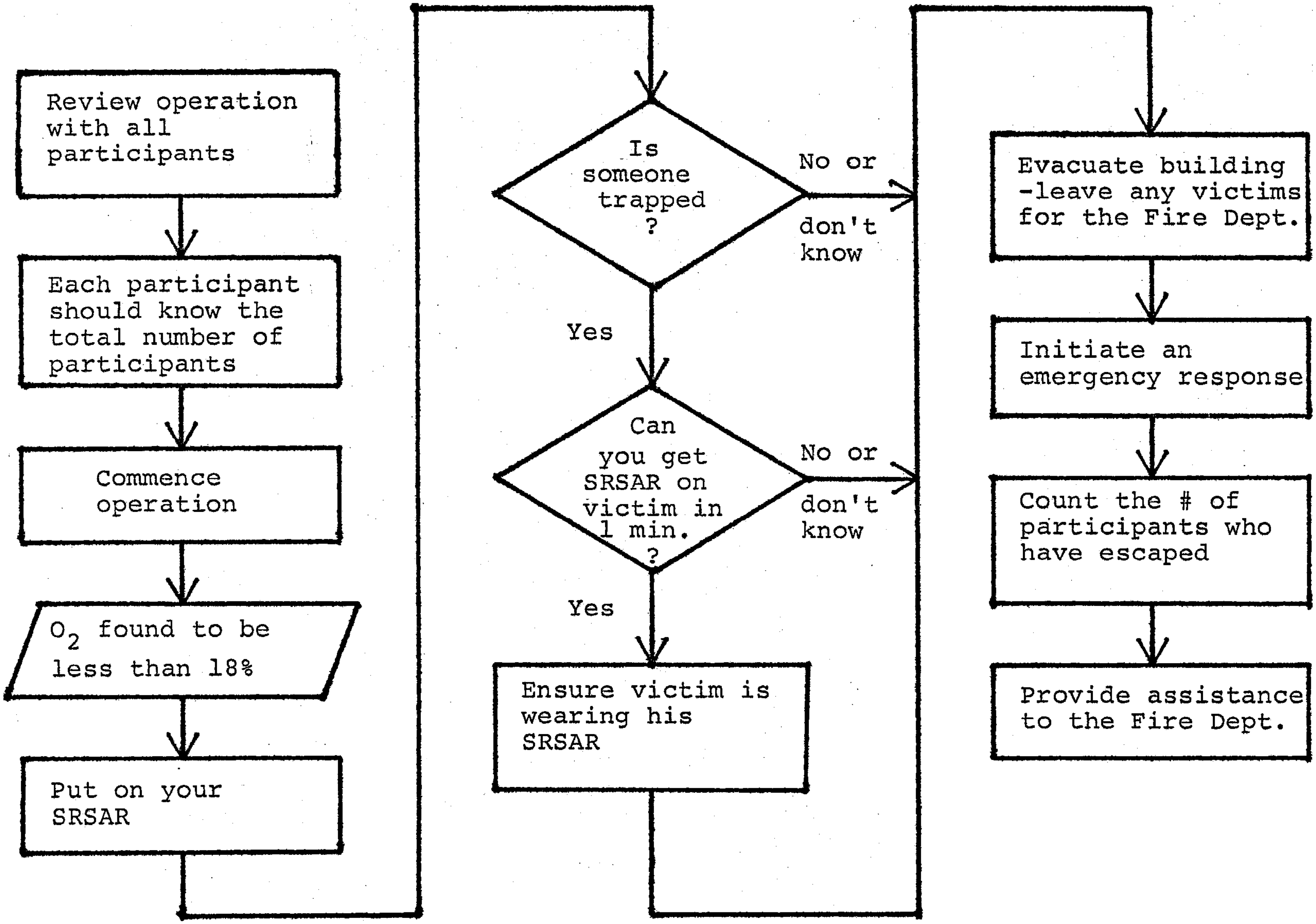
DANGER

OXYGEN DEFICIENCY HAZARD 4

ENTRY AND OCCUPANCY MUST BE SUPERVISED BY THE FIRE DEPARTMENT.
PRIOR TO ENTRY, ALL PERSONNEL MUST HAVE THE FOLLOWING:
- . A PERSONAL OXYGEN MONITOR
- . A SELF-CONTAINED BREATHING APPARATUS (SCBA)
- . TRAINING IN OXYGEN DEFICIENCY HAZARDS AND USE OF SCBA'S
- . MEDICAL APPROVAL FOR OXYGEN DEFICIENCY HAZARD WORK AND SCBA USE.

ACTIVATE VENTILATION PRIOR TO OCCUPATION.

Figure 3



Review operation with all participants
Each participant should know the total number of participants
Commence operation
O_2 found to be less than 18%
Put on your SRSAR
Is someone trapped ?
No or don't know
Yes
Can you get SRSAR on victim in 1 min. ?
No or don't know
Yes
Ensure victim is wearing his SRSAR
Evacuate building -leave any victims for the Fire Dept.
Initiate an emergency response
Count the # of participants who have escaped
Provide assistance to the Fire Dept.

Figure 4

Figure 5


INSTRUCTIONS
1. TURN UNIT ON-WAIT 3 MIN. FOR STABILIZATION.
2. ADJUST CAL. SCREW FOR 21% IN FRESH AIR.
3. AFTER LBA PLACE ON CHARGE 12-14 HRS.
LP-COM-30
LUMIDOR SAFETY PRODUCTS
MIAMI FLORIDA
SER. NO. 125
Fermi National Accelerator Labora